

Towards Simulation Based Acquisition: RMS Initiatives

Louisa Guise

Sr. Manager Systems Engineer

Raytheon Missile Systems,

Tucson, Arizona

Simulation at Raytheon Missile Systems

- **RMS uses Modeling and Simulation (M&S) for operations analysis, proposal support, engineering design, integration & test and performance analysis.**
- **Types of M&S include constructive, virtual and live.**
- **Constructive simulations include**
 - **Missile 6 Degree of Freedom (6DOF) or Integrated Flight Simulation (IFS)**
 - **Computer-in-the-Loop (CIL) simulations**
 - **Hardware-in-the-Loop (HWIL) simulations**
 - **System-in-the-Loop (SIL) simulations**
 - **Operational Analysis Models (GOTS and internally developed)**
- **Virtual simulations include**
 - **Wargaming lab**
 - **WINS Center**
- **Live simulations**

Simulation is key to our system design, integration and test

Call to Action: We needed a consistent simulation process

- **Current RMS is a merging of multiple different legacies including Hughes, TI, Raytheon, General Dynamics and many engineers hired over the last 3 years.**
- **The results of this merging were multiple processes for developing and using simulations.**
- **A Simulation Working Group (SWG) was formed in 1999 to create a common, consistent vision and process for simulation at RMS.**
- **Simulation process is slowly being adopted as new programs start or existing programs reach reasonable injection points.**

Disciplined simulation development required cultural change

RMS SBA Goals and Benefits

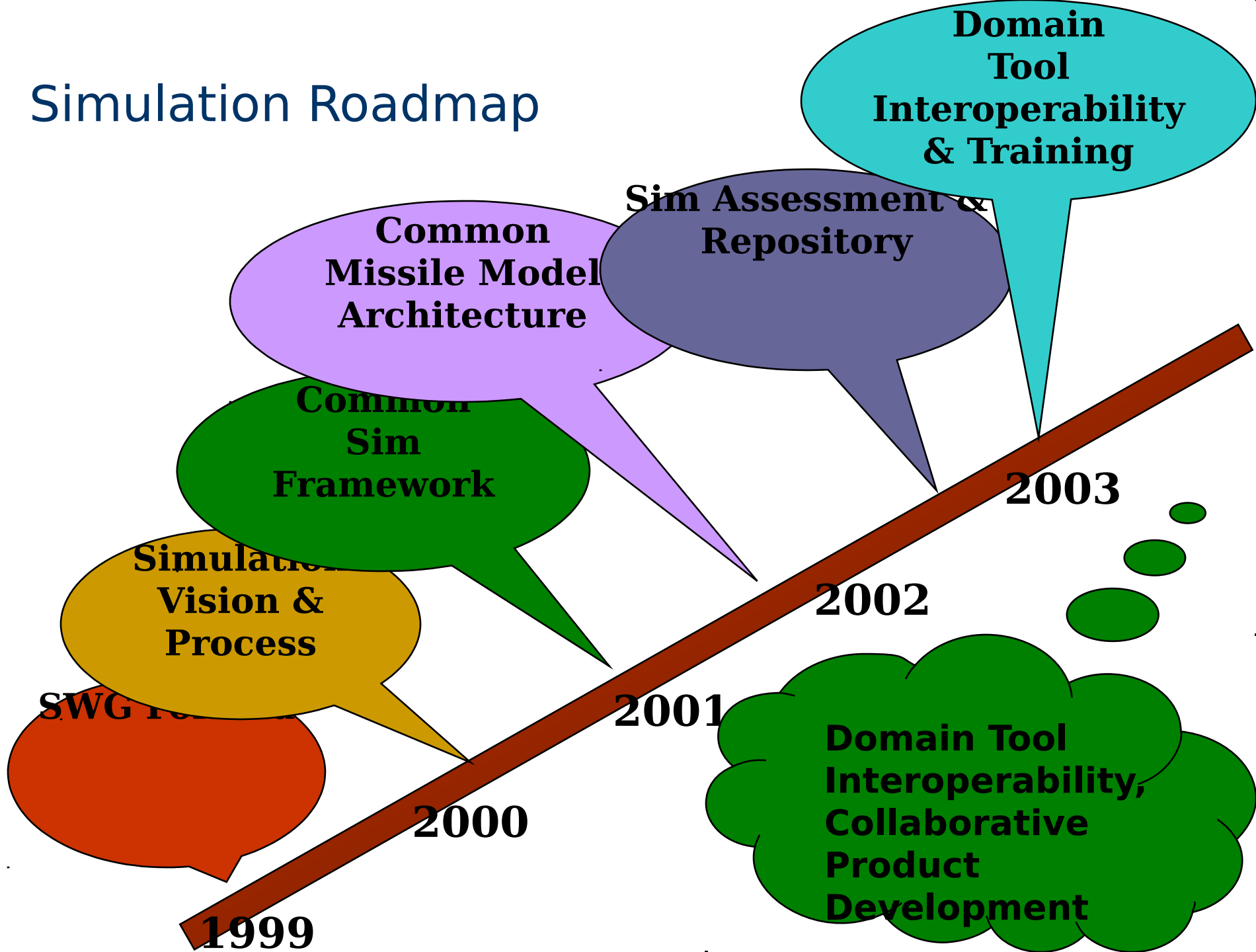
Common Processes

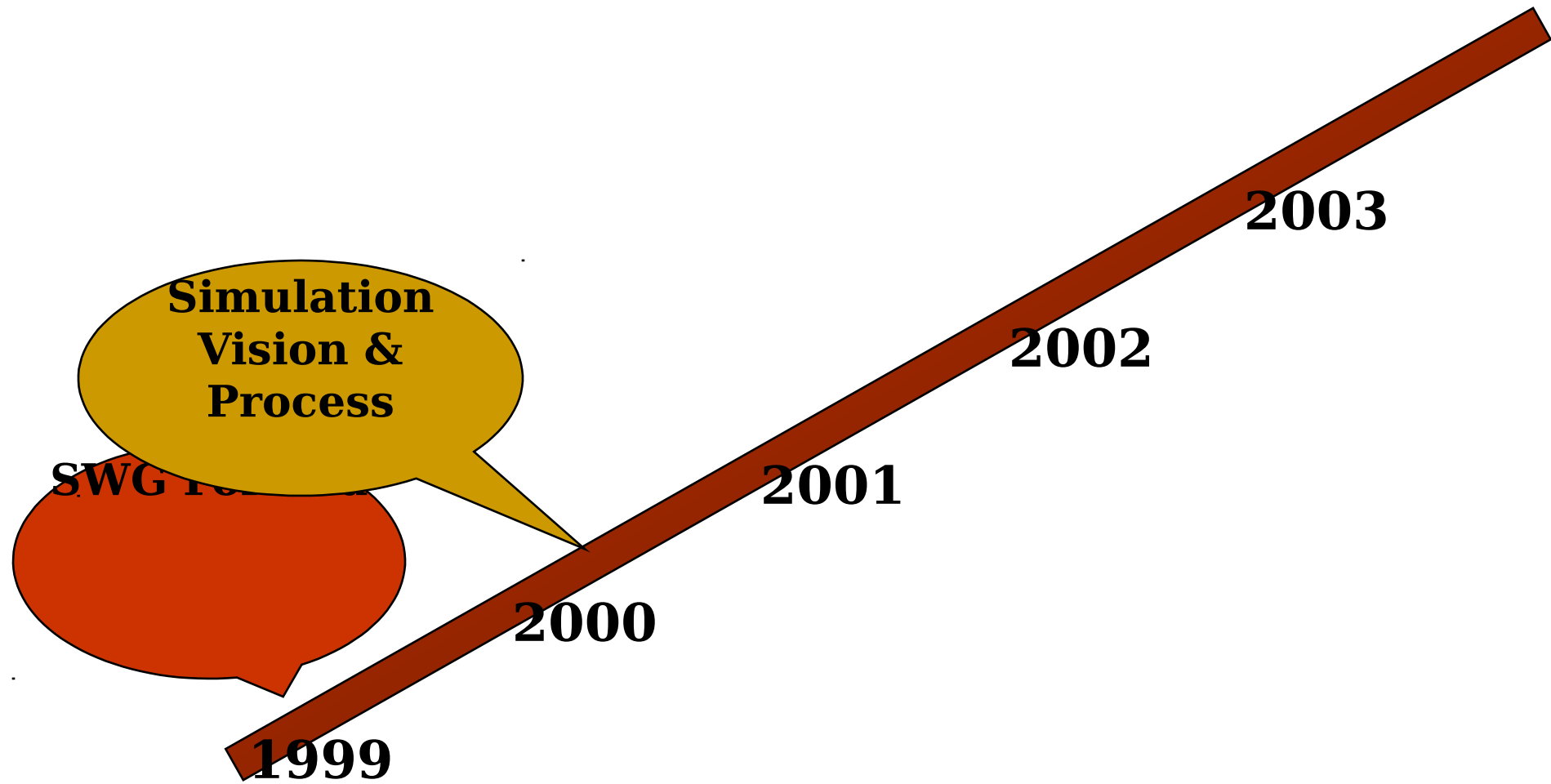
- **Reduces learning curve costs**
- **Reduces cost of development by maximizing re-use**
- **Increases quality / credibility of simulation by establishing good solid engineering**

Reduce redundancies in missile system design, development, integration and test

- **Developing embedded software within simulation reduces redundancies in algorithm design to software implementation process**
- **Using common simulation baseline for proposal, system design, performance evaluation, and integration reduces redundancies in simulation development**
- **Making design tools interoperable with each other and with simulation reduces redundancies in establishing**

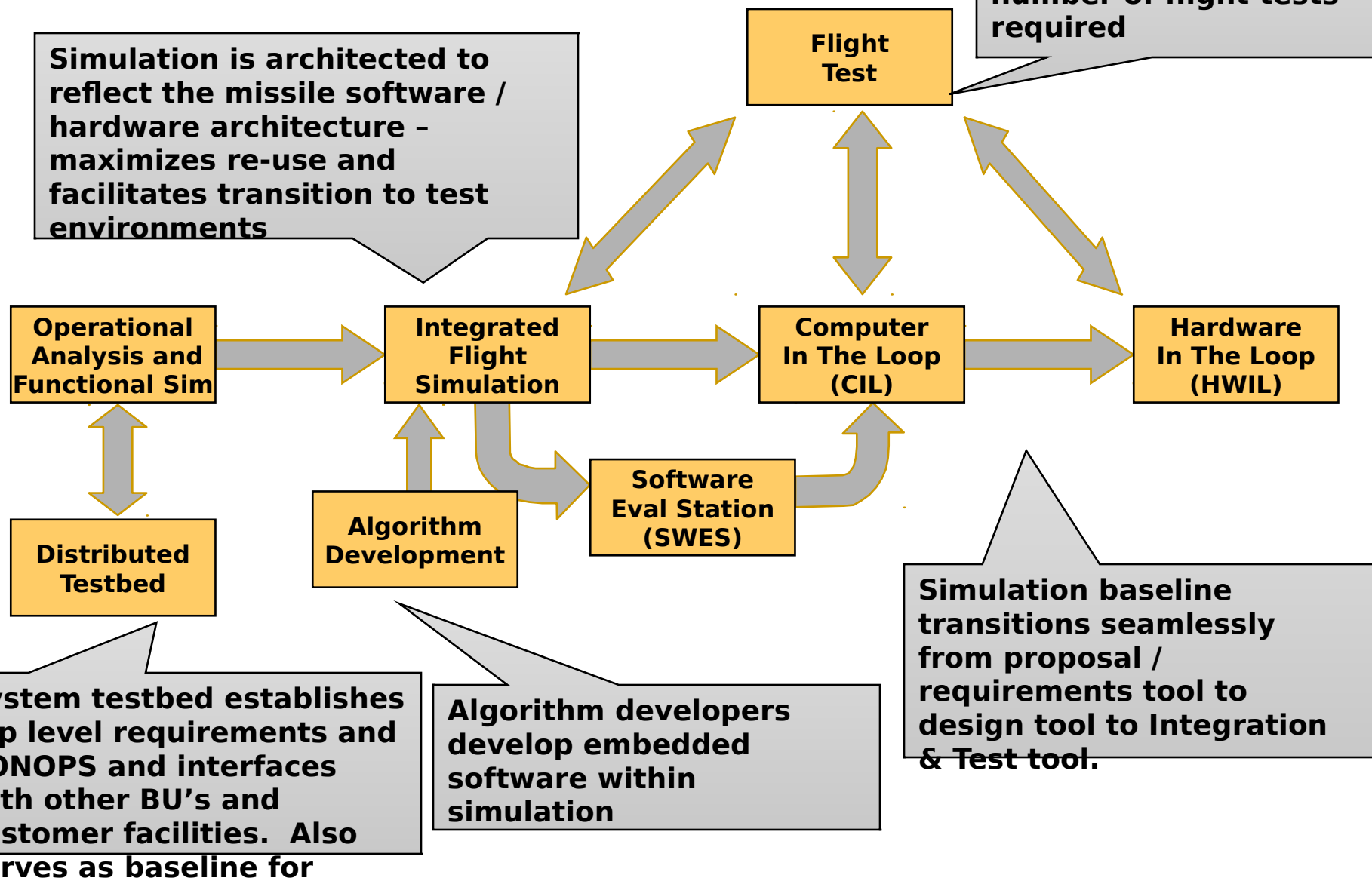
Simulation Roadmap





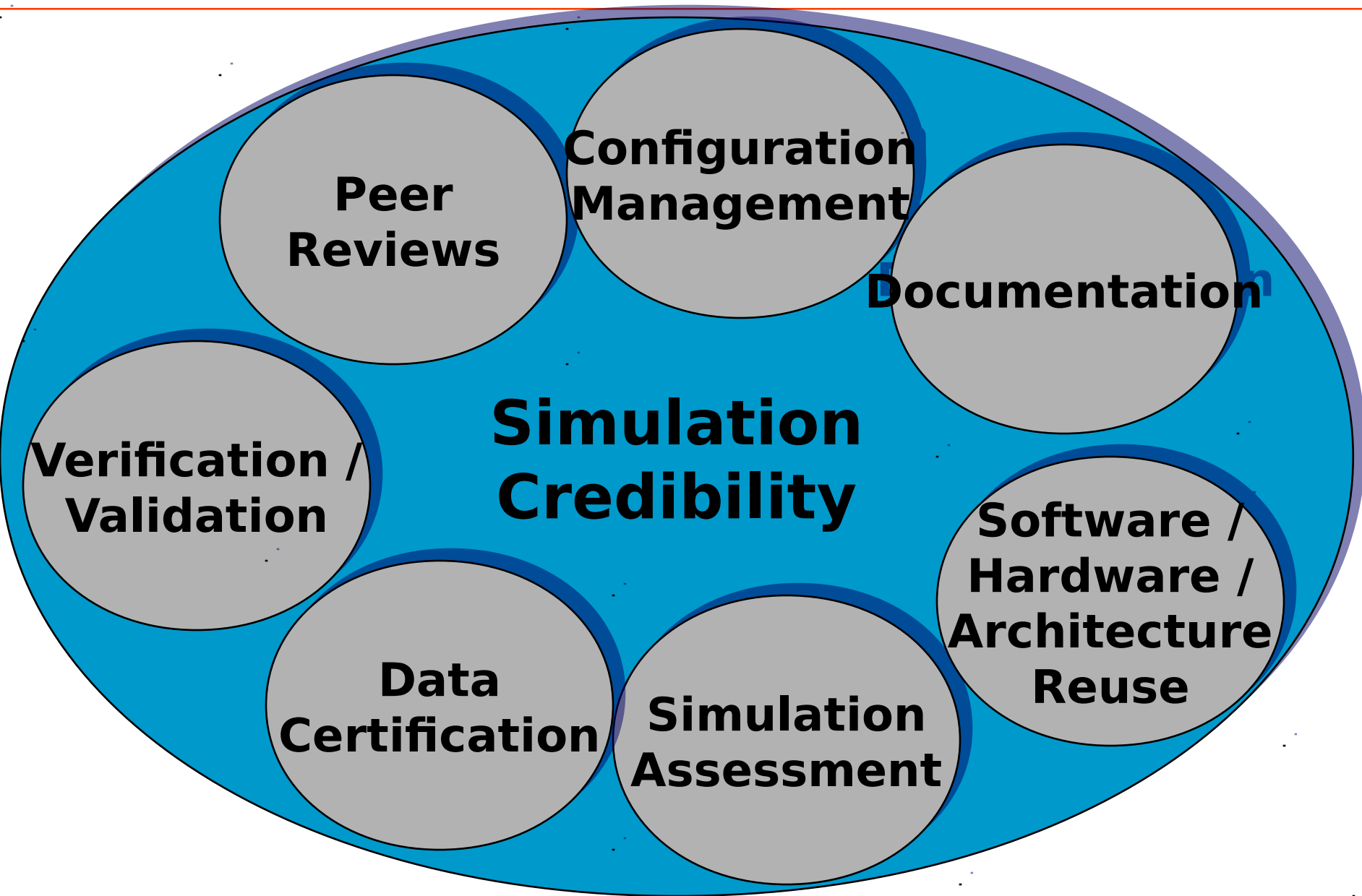
Vision: A simulation process that seamlessly supports Design, Development, Integration, Test and Manufacturing across all programs.

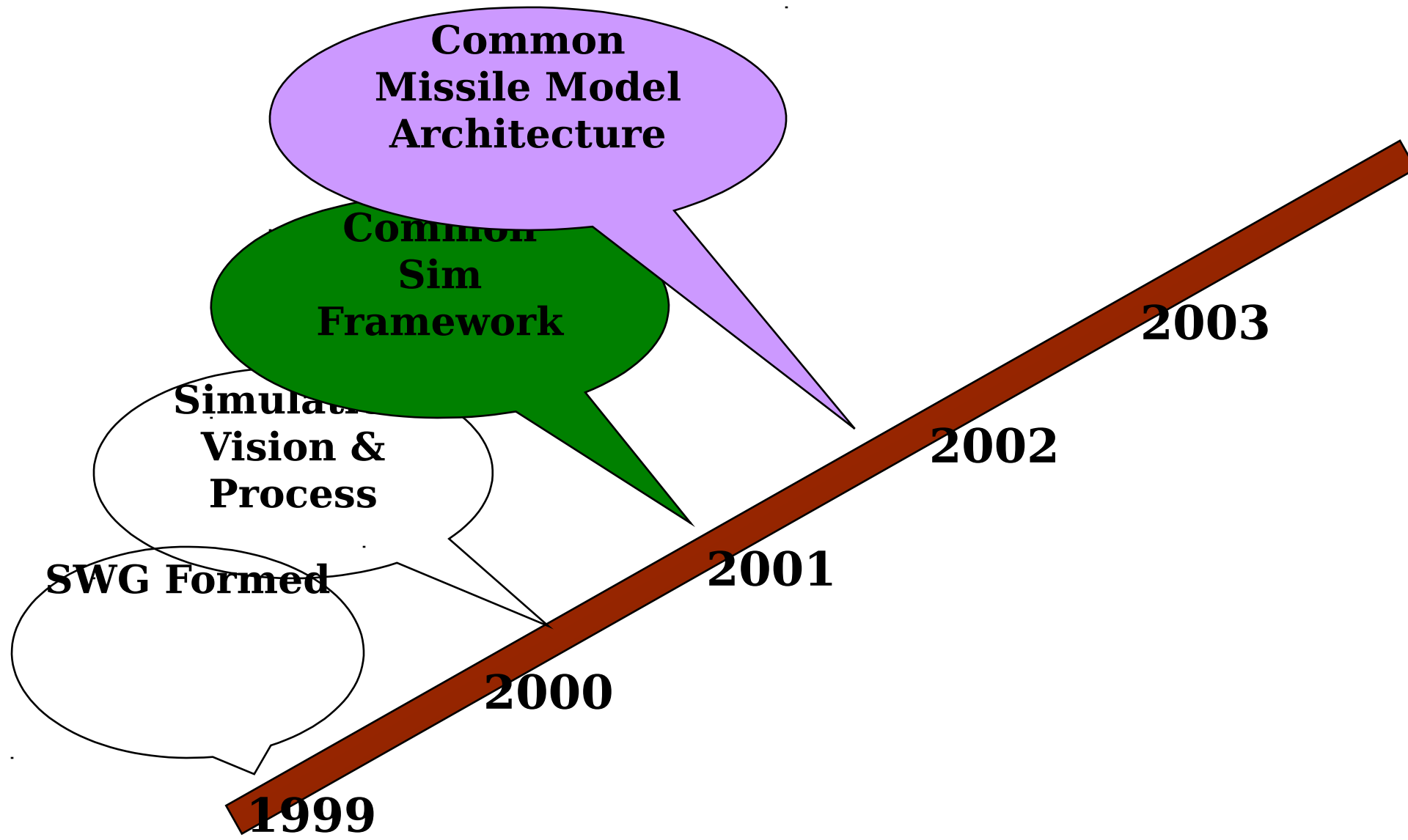
Raytheon



Simulation Process Ensures Simulation Affordable Credibility

Raytheon



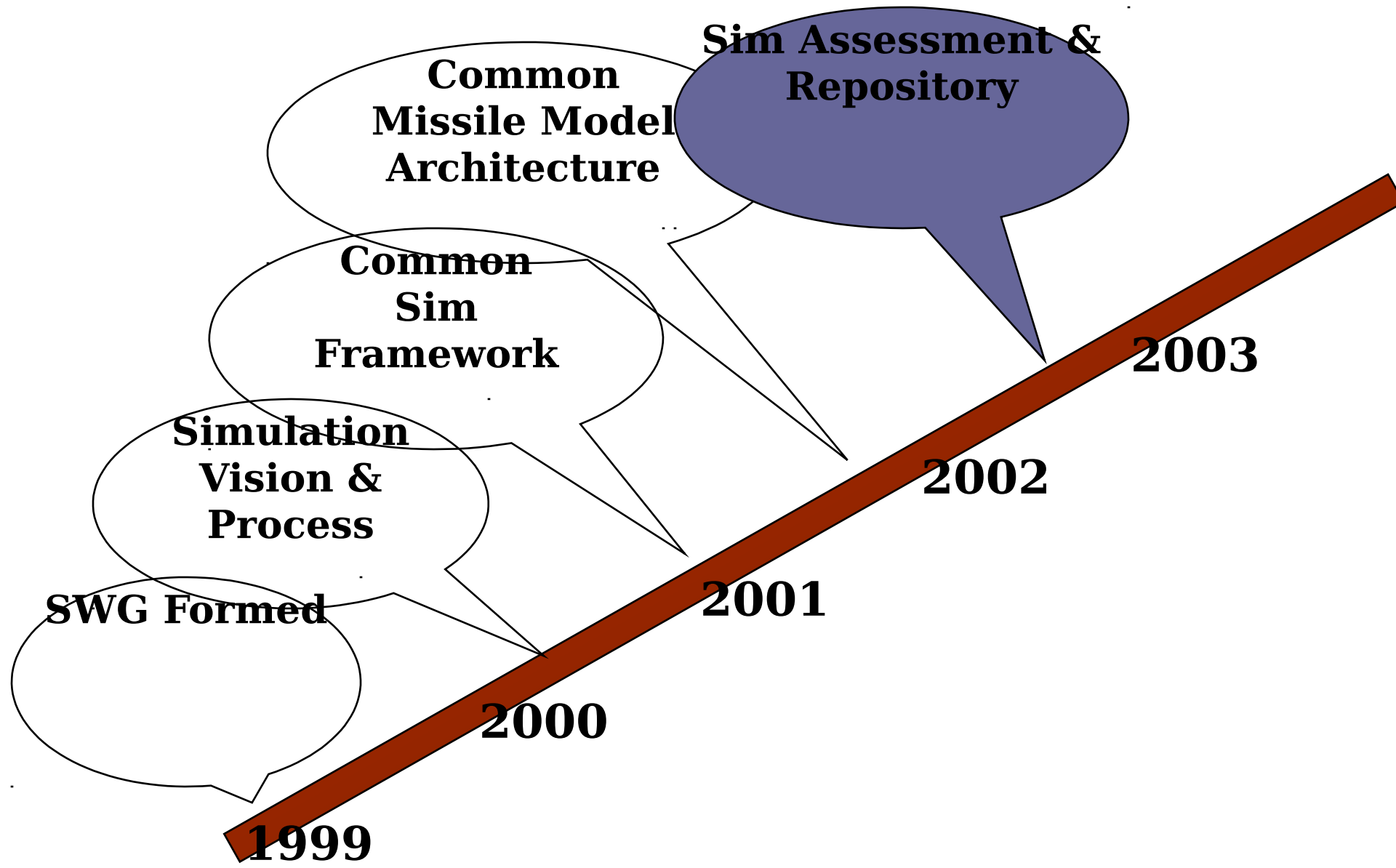


- **RMS has adopted a Common Simulation Framework and Architecture**
- **This facilitates re-use, tool interoperability and improves employee productivity as they transition from one program the next**
- **Simulation framework is the structure within which a simulation “lives” - it is independent upon the application code.**
- **Our missile model architecture defines the objects necessary to represent a missile system and its environment.**
 - **Objects are defined by their interfaces and functionality**
 - **Objects are represented as parent classes within C++**
 - **Objects represent logical decomposition of missile into component objects**

- **RMS has adopted the Command Simulation Framework (CSF) as our standard framework.**
- **CSF provides the “glue” needed for simulation development including**
 - **Scheduler**
 - **Integration algorithms and state management**
 - **Inter-object communications**
 - **Mathematics libraries and vector manipulation**
 - **Input / output capability**
 - **Monte Carlo processing control**
 - **Graphical User Interface**

Common Simulation Framework Overview

- **Developed by Army & University of Huntsville**
- **Currently hosted on two platforms**
 - **SGI for lab and real time operation**
 - **Linux for the desktop**
- **Distributed as “Open source”**
 - **All source code is delivered**
 - **All build tools are “public license”**
- **Raytheon participates as a co-developer**
 - **Added some integration and I/O routines desired by programs**
 - **Army shares in adding features and Raytheon leverages off effort**
- **Low overhead**
- **Abstracts complex C++ functionality away from modelers and algorithm developers with use of templates**
- **Developers do not need to know specifics of CSF framework or be experts in C++**
- **CSF Users Group meets every other Wednesday to discuss issues and improvements.**



Simulation Assessment

- **The purpose of the simulation assessment tool is to provide a mechanism for programs to determine the level of maturity or credibility of their simulation(s).**
- **The results of the tool are meant to be used by programs to highlight areas that need improvement.**
- **Note that the results need to be interpreted for the phase of the program. For example**
 - **Some programs may be too early in their lifecycle to care about validation, since no validation data may be available.**
 - **Some programs might be so far into their lifecycle that elements of some of the categories may no longer apply.**
- **Assessments may be performed by an independent assessor or as a self-assessment tool**
 - **For independent assessment, assessor will need support from simulation subject matter experts**
- **Anyone with simulation knowledge can perform assessment**

Assessment Tool Description

- **Tool is composed of 26 questions in 6 key areas**
 - **Development process**
 - **Useability**
 - **Supportability**
 - **Configuration Management**
 - **Verification / Validation Status**
 - **Customer Satisfaction**
- **Each question asks the assessor to rate the simulation's current status as 0 (red), 1 (yellow), 2 (green) or 3 (blue).**
 - **0 = the simulation does not do the topic at all**
 - **3 = simulation nirvana with regard to the topic**
- **The assessor must give objective evidence that the simulation does or has done the topic as defined in the question.**
- **Assessment requires approximately 8 hours (depending upon assessors familiarity with simulation)**
- **After assessment tool has been completed, simulation subject matters make recommendations for areas of improvement**

Improvement Strategy

- **Improvement strategy should focus on the areas that are of most concern to the program for its phase of development.**
 - **Proposal or pre-SDD program may not care about V&V status, since no data for validation is available. This type of program may care more about Usability.**
 - **SDD program may care more about Development Process and V&V since these programs have more at stake with regard to trusting the simulation results (e.g., high cost of flight tests!)**

Simulation Assessment Provides Indication of Simulation Health

Numbers in parentheses indicate the weighting factor for each criterion.

Development Process 1.2

Model Implementation (5)	1
Testing (5)	1
Quality of Reviews (4)	1
Ease of Code Mod (3)	1
Output Capability (3)	2
Documentation (3)	1
System Platform (2)	2
Programming Standards (2)	1
Developer Training (2)	0
Code Readability (1)	3

Usability 2.0

Ease of Use (3)	2
Adequate Output (3)	2
User Training (2)	2

Supportability 1.5

Knowledge Base (4)	1
Application Obsolescence (4)	2

Configuration Management 3.0

CM Process (5)	3
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Verification / Validation Status 0.5

V&V Plan (5)	0
Simulation Requirements (4)	1
Simulation Code Correctness (5)	1
Simulation Capability (4)	1
Simulation Validation (5)	0
Simulation Data (5)	0

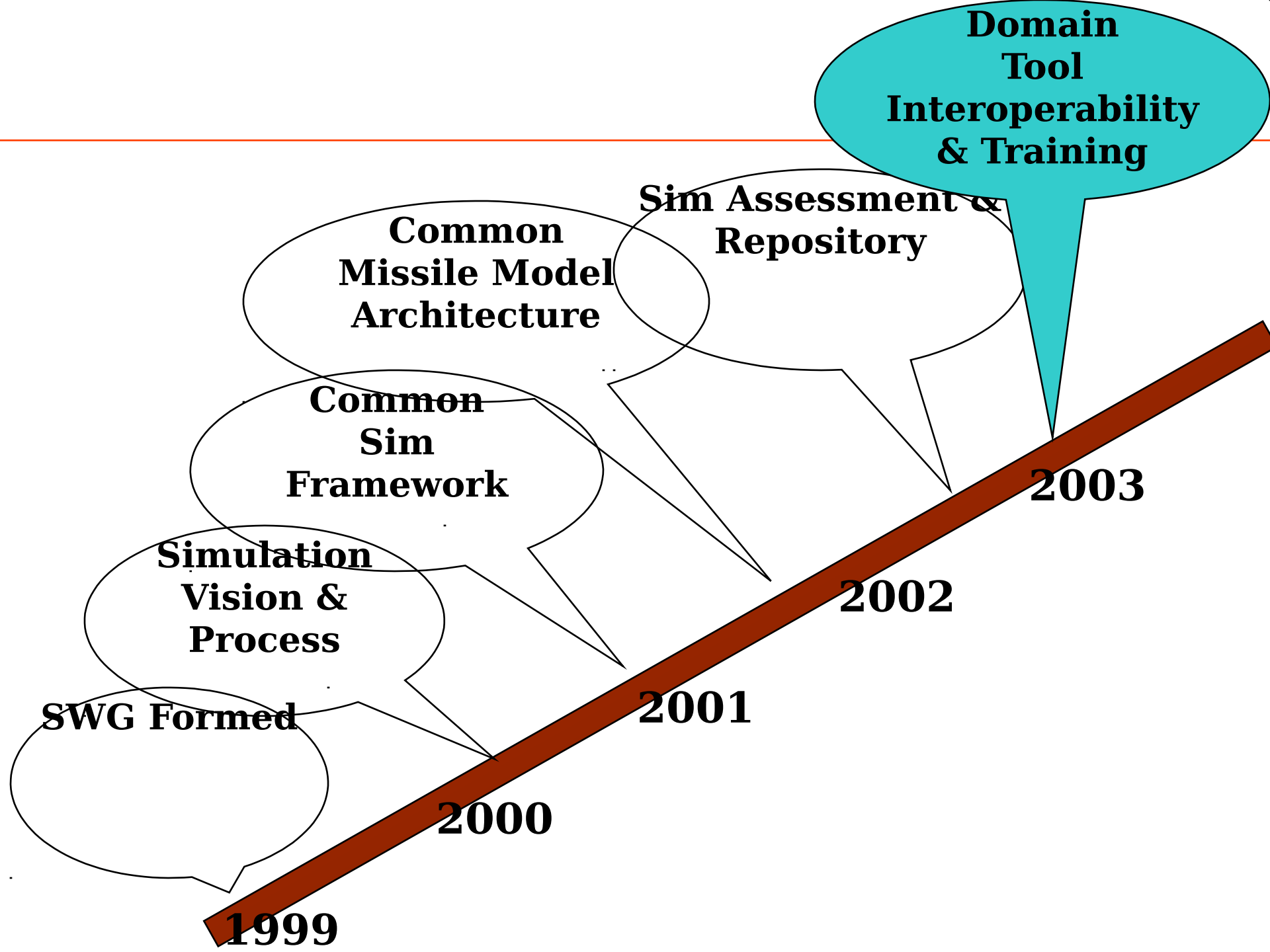
Customer Satisfaction 0.0

Customer Confidence (5)	0
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Overall Score 1.4

Model, Simulation and Tool Repository Facilitates Re-Use

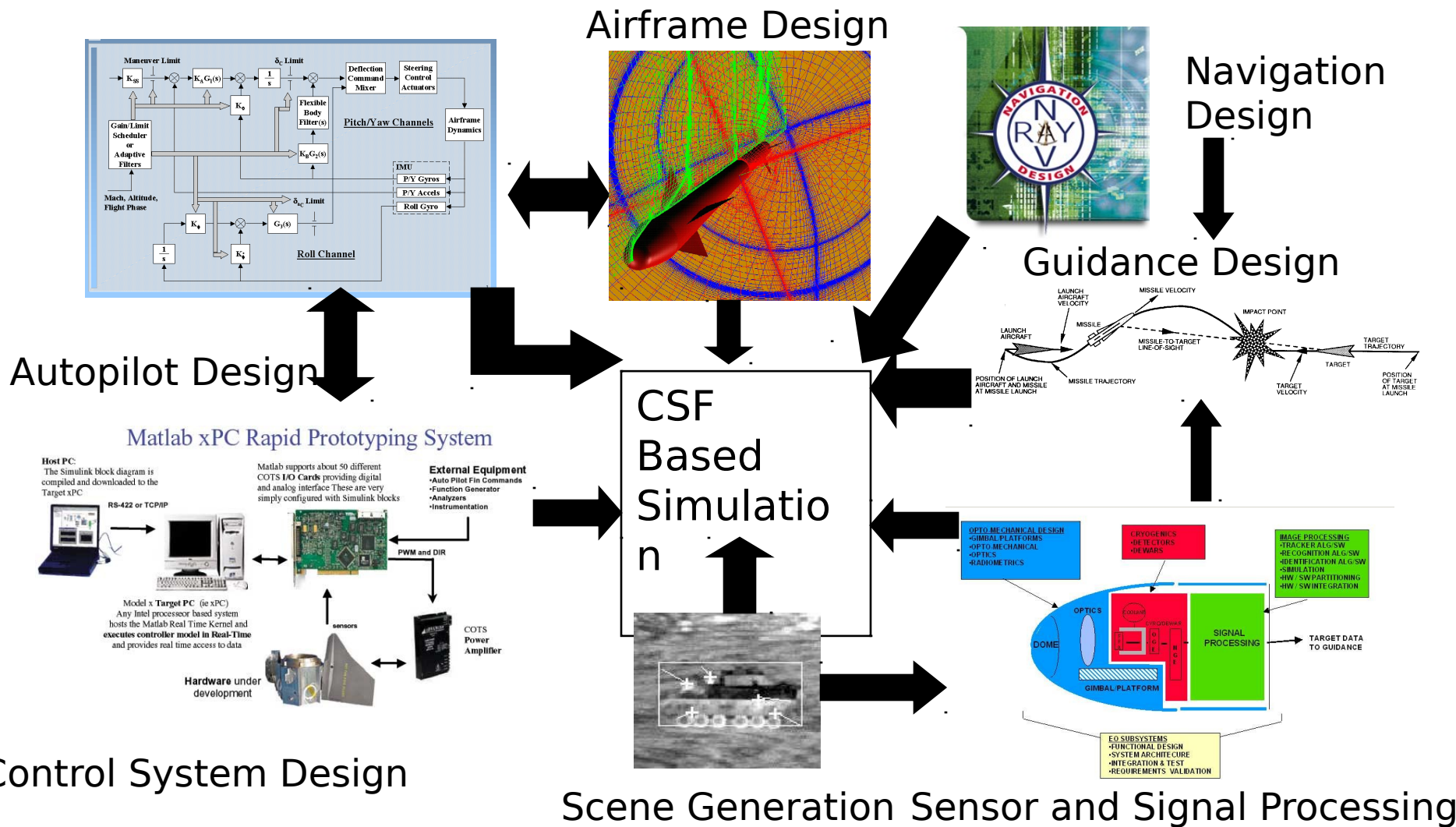
	Repository Questions / Comments / Suggestions Please post your questions and comments here by adding a bulletin	74682	06/21/2002	0	
	Aerodynamic Models Models that provide missile 6DOF forces and moments	HMTJ6485	08/27/2002	17	
	Atmosphere / Environment models Models that establish environmental conditions	74682	06/21/2002	4	
	Autopilot Algorithm / Models Algorithms that create missile control commands	HMTJ6246	08/26/2002	4	
	BMC3I Models Models of Battle Management, Command, Control & Communications	74682	06/17/2002	1	
	Common Simulation Framework Contains the source code, libraries and documentation for CSF	HMT90525	08/26/2002	2	
	Computer Processor Models Contains models representing the missile computer processor	74682	04/08/2002	1	
	Cueing Sensors Models of sensors providing information to missile system	74682	06/17/2002	1	
	EO Environment / Scene Generation Models Contains models depicting EO sensor's environment	lengle	06/17/2002	1	
	EO Seeker Models Hardware models for EO seekers	74682	04/08/2002	2	
	EO Sensor Signal Processing Algorithms / Models EO Signal processing	74682	04/08/2002	1	
	Equations of Motion Missile Dynamics	74682	06/17/2002	8	
	Full-Up Simulations Repository for full-up existing simulations	74682	06/17/2002	4	



Domain Tool Interoperability

- **Effort to ensure that outputs from domain specific tools (e.g., algorithm development tools such as MATLAB) feed the simulations seamlessly**
- **Assumes CSF as the simulation environment although we are working to become “framework agnostic”**
- **Includes explicit processes as well as modifications to tools.**
- **Intent is to connect tools from various disciplines and functional organizations.**

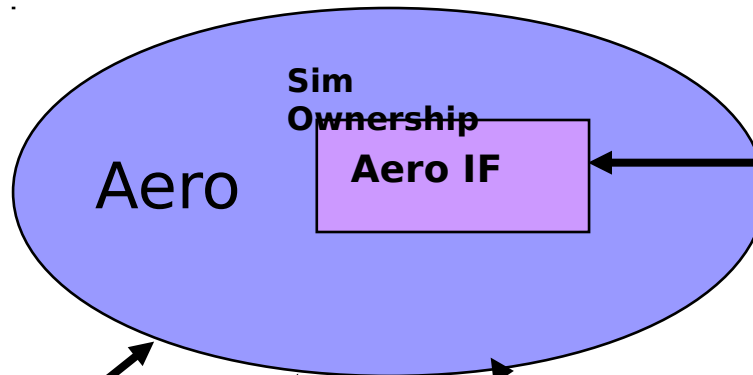
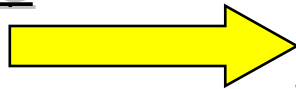
System Design, Integration and Test tools inter-operate seamlessly with CSF based simulations



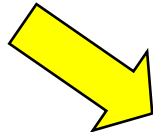
Sim / Tool Interoperability Aerodynamics Example

Raytheon

Aero Base
Class

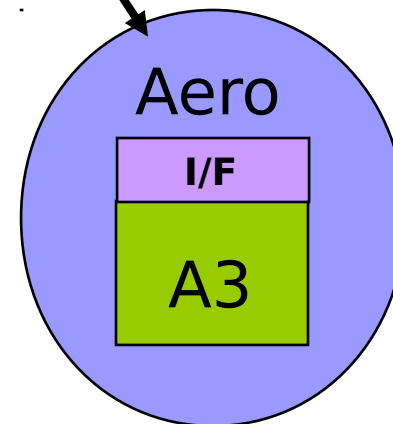
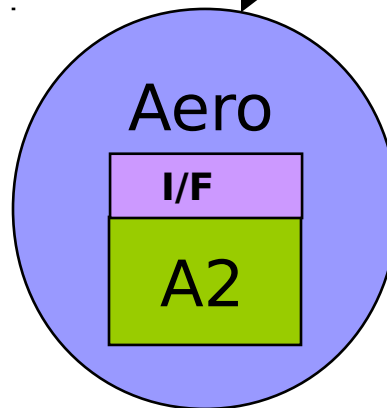
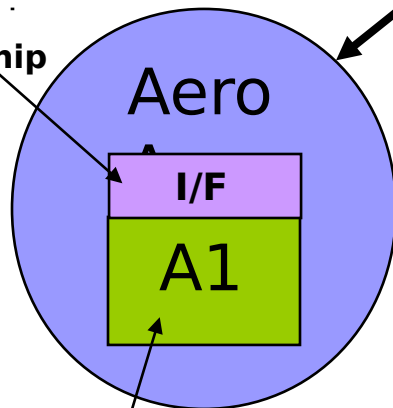


Aero Derived
Classes



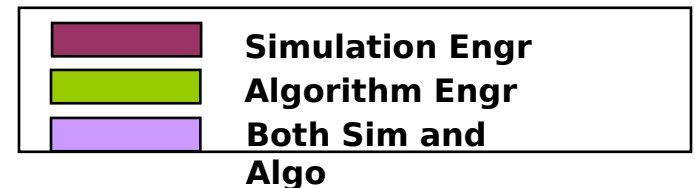
Simulation Ownership

Joint
Ownership



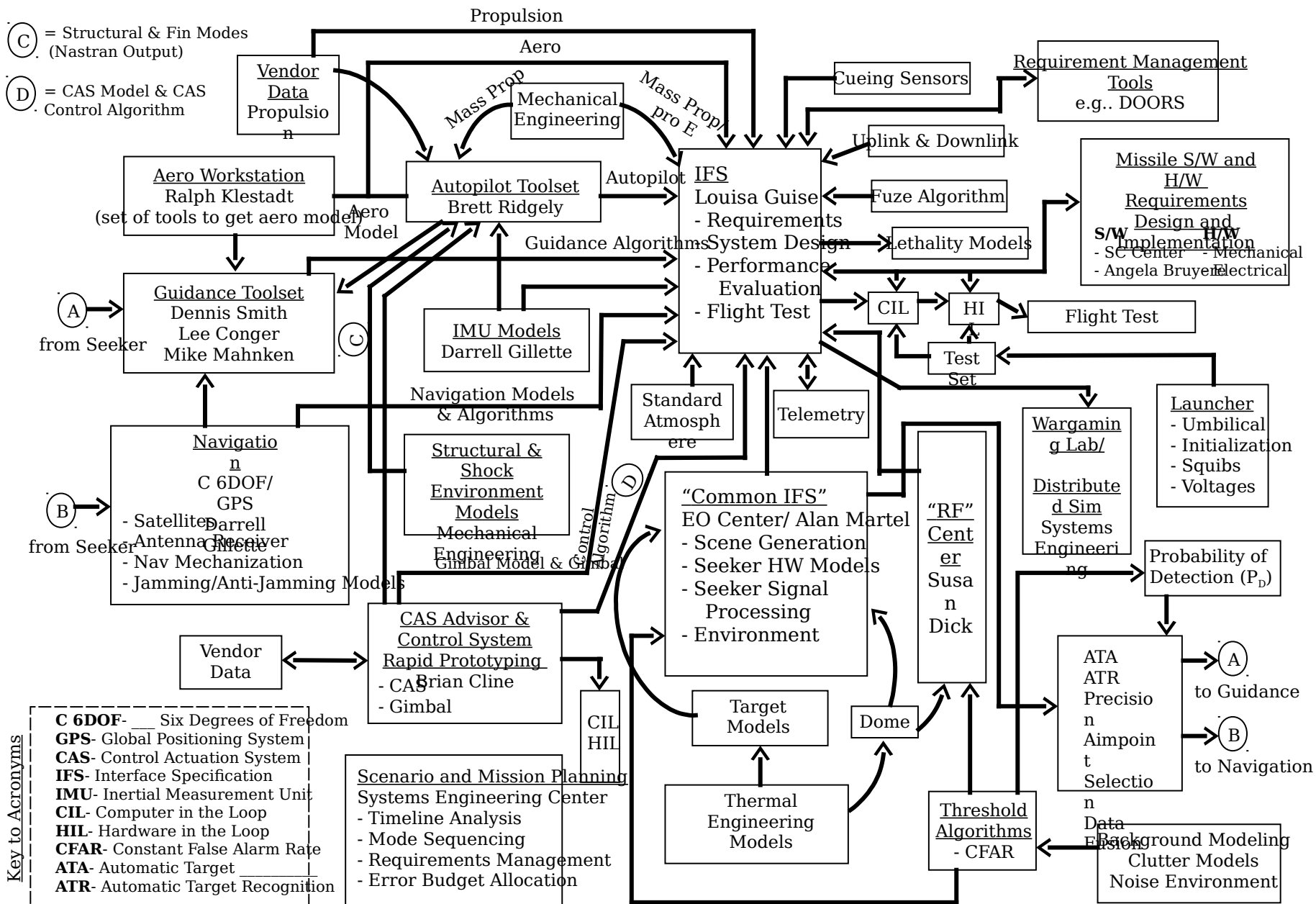
Aero Ownership - from
toolset

**Aero A, B and C may
be plugged and
played**

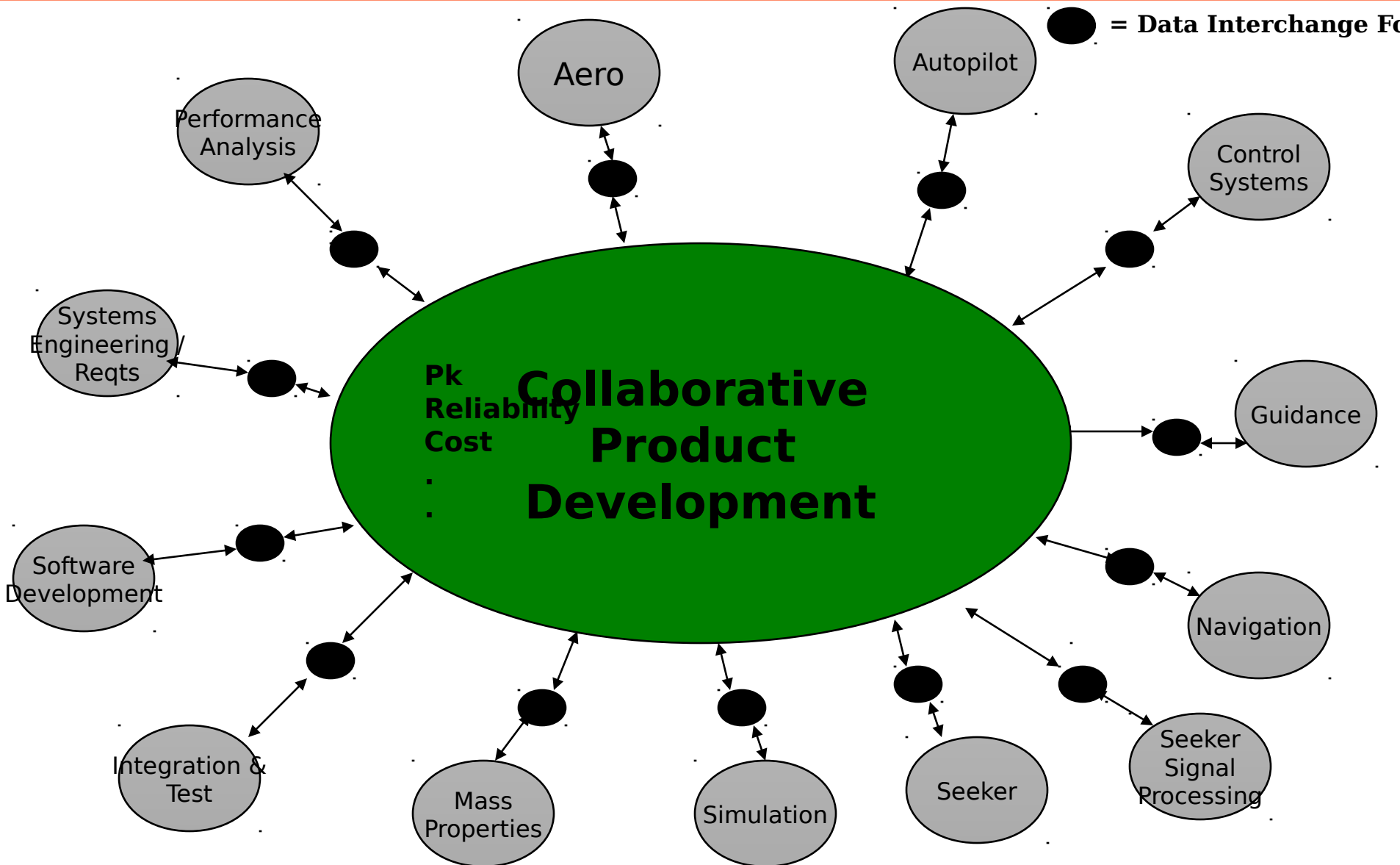


(C) = Structural & Fin Modes
 (Nastran Output)

(D) = CAS Model & CAS
 Control Algorithm



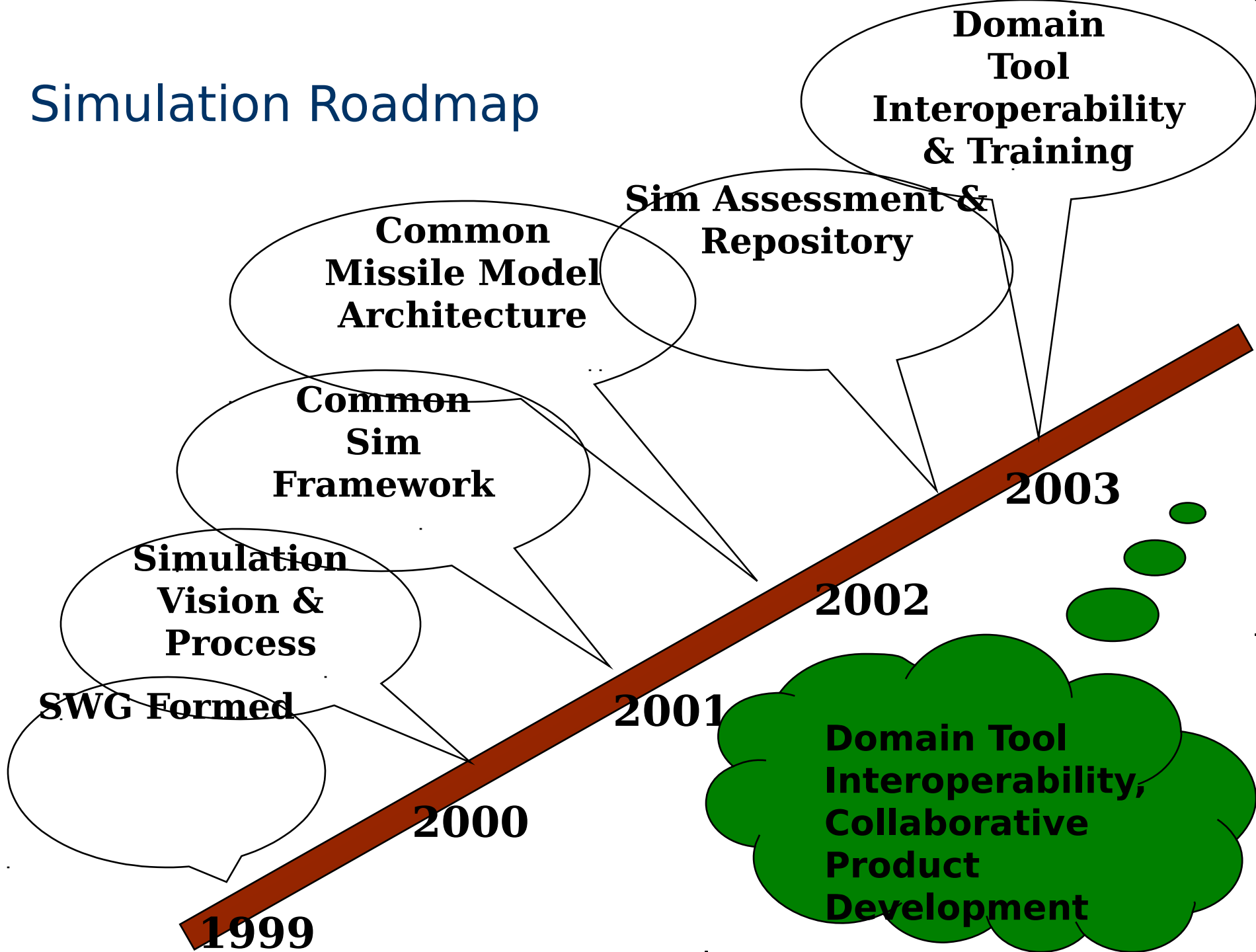
To Be State: Stakeholders are connected and communicating!



Simulation Training

- **RMS has instituted a Simulation Engineer Certification program.**
- **Three levels of certification: Silver, Gold and Simulation Subject Matter Expert**
- **Each level requires classes and practical experience**
- **Certified Simulation Engineers are recognized with plaques, awards and an award event**

Simulation Roadmap



The Future

- **We will continue adding tools to our set of interoperable tools to ensure that all algorithms and designs flow as part of a collaborative product development environment.**

Summary

- **Modeling and Simulation play key roles in system design, integration and test.**
- **RMS has established processes and infrastructure to facilitate CREDIBLE simulations that are EFFICIENT to develop and FLEXIBLE to use in a variety of environments**